CEWQO 2019

Controllable enhancement of non-classical squeezed light in correlated orbital momentum modes

O.V. Tikhonova[1,2] and R.V. Zakharov[1,2],

[1] Physics Department, Lomonosov Moscow State University, Moscow, Russia, 119991

[2] Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia

Abstract

Problem of selection and amplification of modes with different orbital angular momentum of non-classical squeezed light is studied. Methods of controllable enhancement of nonlinear signal in certain correlated azimuthal channels are developed. A problem of loss of photon correlations is investigated for this technique and possible ways to minimize the correlation losses are demonstrated. The possibility of using such schemes for high-resolution measurements is discussed.

Nowadays different types of non-classical states of electromagnetic field are possible to be generated. Among them bright squeezed states of light [1] appears to be the most attractive due to strong correlations between many photons both in the frequency and space domain. An important advantage of such states is their multimode structure. Azimuthal modes are of great interest since they are characterized by certain projection of angular momentum. Light with non-zero orbital angular momentum (OAM) is referred to as a twisted light. Combination of such important physical features as non-classicality, squeezing and twist opens new possibilities for a wide set of perspective practical applications of such light in quantum communications, supersensitive measurements, quantum sensing, quantum imaging and lots of quantum-information applications. For many applications methods of selection of particular spatial modes especially with certain orbital angular momentum accompanied by minimization of the photon correlation losses appear to be of great importance.

In this work we consider the selection and possible amplification of particular spatial modes of bright squeezed light generated in a system of separated nonlinear crystals which can be considered as a non-linear interferometer. For theoretical description we develop fully analytical approach based on the concept of independent collective (Schmidt) modes [2]. In the frame of the Heisenberg representation we obtain fully analytical solution for the evolution of the photon operators for each Schmidt mode and calculate all required characteristics. The most attention is paid to azimuthal modes with non-zero orbital angular momentum. It is shown that though in the far field region channels with different OAM have similar spatial distribution, in the near field they are predominantly localized in different regions of the transverse plane. This feature allows us to separate different OAM channels by holes and masks inserted into the non-linear SU(1,1) interferometer.

In the case of a mask we can selectively block a certain OAM channel and enhance others in a second crystal. By using a hole we can strongly de-amplify a part of transmitted light in the properly tuned second crystal of interferometer due to destructive interference. A problem of loss of photon correlations is investigated for this technique. Ways to minimize the correlation losses are suggested. We demonstrate the possibility of 2 times selective amplification of OAM modes with orbital numbers 1 and 2 in relation to the zero-OAM mode accompanied by minimization of the photon correlation losses. The obtained results are of great importance since usually the zero-OAM channel strongly dominates in azimuthal mode distribution. The possibility of using such schemes for high-resolution measurements is discussed.

We acknowledge financial support of the Russian Science Foundation Grant №19-42-04105

[1] K.Yu. Spasibko, T.Sh. Iskhakov, M.V. Chekhova, *Spectral Properties of High-Gain Parametric Down-Conversion* Optics Express **20**, 7507-7515 (2012).

[2] P Sharapova, A M Pérez, O V Tikhonova and M V Chekhova, *Schmidt modes in the angular spectrum of bright squeezed vacuum* Phys. Rev. A **91**, 043816 (2015).